

GEOTECHNICAL PERFORMANCE USING ALKALINE ACTIVATED FLY
ASH FOR SOIL MIXTURES WITH AND WITHOUT POLYPROPYLENE
FIBERS

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*I would like to dedicate this thesis to
my beloved FATHER and MOTHER
my WIFE and my CHILDREN
my SISTER and BROTHERS*



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ABSTRACT

Soil stabilization is one of the well-known methods to treat problematic soils. Its advantages over soil replacement are that of low cost and fast implementation. Alkaline activation (geopolymerization) of soft soils is a new technique that has been addressed recently to stabilize soft soils. Though its strengthening mechanism and final product in terms of stiffness and brittleness resembles that observed by cemented soils. In other words, the residual strength emerged when approaching failure is very low resulting in immediate damage of building structures. Therefore, the aforesaid shortcoming needs to be overcome particularly when horizontal displacement is present. In this regard, Potassium hydroxide was added to a mix of fly ash class F and polypropylene fibers to stabilize and reinforce Kaolin clay (S1) and marine clay (S2) respectively. The fly ash solid ratio was considered to be 10%, 20%, 30%, 40%, while polypropylene fiber proportions adapted for the study were 0.5%, 0.75%, 1% 1.25%. Compressive-, flexural- and indirect tensile tests as well as California bearing capacity (CBR)- & one dimensional consolidation tests were conducted. The compressive strength results of 28 days curing regime confirm the 40% fly ash mixture to contribute to the sharpest increase in compressive strength at 3680, 6980 kPa respectively. Though a sharp drop was observed. With the inclusion of polypropylene fibers, the mode of failure changed to a more ductile one resulting in peak strength values at 6450 kPa and 5834 kPa respectively. Besides, flexural and indirect tensile results were recorded to be 1555, 1770, 1833, 1819, 1541, 1777, 1545 and 1440 kPa for S1F40, S1FR0.75, S2F40 and S2FR0.75 respectively. In addition, the incorporation of fly ash and polypropylene fibers increased the CBR values of all pretreated mixtures indicating values of 51.2%, 69.8%, 48.1% and 59% for S1F40, S1FR0.75, S2F40 and S2FR0.75 respectively. Finally, the compression index and the preconsolidation pressure exhibited a substantial decrease and increase at 0.043,

0.076, 0.047, 0.104 and 900 kPa, 400 kPa, 500 kPa, 240 kPa for S1F40, S1FR0.75, S2F40 and S2FR0.75 respectively. It is to conclude, that the proposed new technique has a promising future to be used in soil stabilization domain where horizontal displacement is expected.



ABSTRAK

Penstabilan tanah merupakan salah satu kaedah yang terkenal digunakan untuk merawat tanah bermasalah. Kelebihannya ke atas kaedah penggantian tanah adalah dari segi kos yang rendah dan pelaksanaan yang cepat. Pengaktifan beralkali (*geopolimerization*) tanah lembut merupakan teknik baharu untuk menstabilkan tanah lembut. Walaupun, mekanisma pengukuhan dan produk akhir dari segi kekerasan dan kerapuhan menyerupai apa yang diperhatikan pada tanah yang dikukuhkan. Dalam kata lain, kekuatan lebihan yang terhasil adalah rendah semasa menghampiri kegagalan mengakibatkan kerosakan serta-merta pada struktur bangunan. Oleh yang demikian, kelemahan yang disebutkan di atas perlu diatasi terutamanya apabila terdapat kehadiran pergerakan mendatar. Sehubungan dengan itu, Potassium Hidroksida telah ditambah kepada campuran abu terbang kelas F dan gentian polipropilena untuk menstabilkan dan memperkukuhkan tanah liat Kaolin (S1) dan tanah liat marin (S2). Nisbah pepejal abu terbang yang dipertimbangkan adalah 10%, 20%, 30% dan 40%, manakala perkadaran gentian polipropilena yang disesuaikan untuk kajian ini adalah 0.5%, 0.75% 1% dan 1.25%. Ujian mampatan, lenturan dan tegangan tidak langsung serta ujian nisbah galas *California* (CBR) dan pengukuhan satu-dimensi telah dijalankan dalam kajian ini. Keputusan kekuatan mampatan daripada pengawetan selama 28 hari mengesahkan campuran 40% abu terbang menyumbang kepada peningkatan kekuatan mampatan yang paling ketara iaitu 3680 kPa dan 6980 kPa. Namun begitu, kejatuhan mendadak turut diperhatikan. Dengan penambahan gentian polipropilena, mod kegagalan bertukar menjadi lebih lentur dan hasilnya nilai kekuatan puncak menjadi 6450 kPa dan 5834 kPa. Selain itu, keputusan ujian lenturan dan tegangan tidak langsung merekodkan nilai 1555, 1770, 1833, 1819, 1541, 1777, 1545 dan 1440 kPa masing-masing bagi sampel S1F40, S1FR0.75, S2F40 dan S2FR0.75. Di samping itu, campuran abu terbang dan

gentian polipropilena meningkatkan nilai CBR semua sampel terawat iaitu 51.2%, 69.8%, 48.1% dan 59% masing-masing untuk sampel S1F40, S1FR0.75, S2F40 dan S2FR0.75. Akhir sekali, indeks pemampatan tanah dan tekanan pra-pengukuhan menunjukkan penurunan dan kenaikan yang ketara iaitu 0.043, 0.076, 0.047 dan 0.104 bagi 900 kPa, 400 kPa, 500 kPa dan 240 kPa masing-masing untuk sampel S1F40, S1FR0.75, S2F40 dan S2FR0.75. Ia menyimpulkan bahawa teknik baharu yang dicadangkan mempunyai potensi untuk digunakan bagi penstabilan tanah di mana pergerakan mendatar adalah dijangka.



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LIST OF SYMBOLS AND ABBREVIATIONS

μm	-	Micrometer
$^{\circ}\text{C}$	-	Celsius degree
AAG	-	Alkali activated grout
AAS	-	Alkali activated soil
Al	-	Aluminum
Al_2O_3	-	Aluminum oxide
A/S	-	Activator solid ratio
As_2O_3	-	Diarsenic trioxide
A-S-H	-	Aluminum silicate hydrate
ASTM	-	American society for testing and material
BaO	-	Barium oxide
BFA	-	Badarpur fly ash
BS	-	British standard
BTS	-	Brazilian tensile test
C	-	Carbon
C 1, 3, 7 %	-	Cement content in respect to solid
Ca^{++}	-	Calcium ion
$(\text{Ca}_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_{12} \cdot 26\text{H}_2\text{O})$	-	Ettringite
CaCO_3	-	Calcium carbonate
C-A-H	-	Calcium aluminum hydrate
CaO	-	Calcium oxide
$\text{Ca}(\text{OH})_2$	-	Calcium hydroxide
CPB	-	Cemented paste backfill
CBR	-	California bearing capacity
Cc	-	Compression index

CEC	-	Cation exchange capacity
CH	-	High plasticity clay
CH ₃	-	Hydrocarbon, Methyl group
CL	-	Low plasticity clay
Cm ² /g	-	Unit of fly ash specific area
CO ₂	-	Carbon dioxide
CO ⁻³	-	Carbonate ion
CSH	-	Calcium silicate hydrate
CuO	-	Copper oxide
Cv	-	Coefficient of consolidation
D	-	Specimen diameter
d	-	Day
E	-	Young's modulus
EDS	-	Energy dispersive x-ray spectrometry
FA	-	Fly ash
Fe	-	Iron
Fe ₂ O ₃	-	Ferric oxide
FRC	-	Fiber reinforced concrete
FRS	-	Fiber reinforced soil
FS	-	Flexural strength
FTIR	-	Fourier transform infrared spectroscopy
Ga ₂ O ₃	-	Gallium Oxide
GGBS	-	Ground granulated blast- furnace slag
Gpa	-	Giga pascal
H	-	Hydrogen
h	-	hour
H ₂ O	-	Water
K	-	Potassium
KBr	-	Potassium bromide
Kg	-	Kilogram
K ₂ O	-	Potassium oxide
KOH	-	Potassium hydroxide

KN	-	Kilo newton
L/150	-	Finale deflection at failure
L/600	-	Deflection at the point where nonlinearity begins
LL	-	Liquid limit
M	-	Molarity
M30, 50	-	Different grade of concrete mix
MDD	-	Maximum dry density
Mg	-	Magnesium
MgO	-	Magnesium oxide
MnO	-	Manganese oxide
MPa	-	Mega pascal
Mv	-	Coefficient of volume compressibility
n	-	degree of polycondensation
Na	-	Sodium
N-A-S-H	-	Sodium aluminosilicate hydrate
Na ₂ O	-	Sodium oxide
NaOH	-	Sodium hydroxide
Na ₂ OSiO ₃	-	Sodium silicate
NFA	-	Neyveli fly ash
OH-	-	hydroxide ion
OH-(aq)	-	soluble hydroxide
OMC	-	Optimum moisture content
Pc	-	preconsolidation pressure
PE	-	Polyethylene
PH	-	Potential of Hydrogen
PI	-	Plasticity index
PL	-	Plastic limit
PP	-	Polypropylene
Rb ₂ O	-	Rubidium oxide
RHA	-	Rice husk ash
RG	-	Red gypsum
S1	-	light brown Kaolin Clay

S2	-	Marine clay
SEM	-	Scanning electron microscopy
Si	-	Silicon
SiO ₂	-	Silicon dioxide
SO ₃	-	Sulfite
SrO	-	Strontium oxide
UCS	-	Unconfined compressive strength
USA	-	United State of America
UTHM	-	University Tun Hussein Onn Malaysia
TiO ₂	-	Titanium dioxide
Tm ₂ O ₃	-	Thulium oxide
V ₂ O ₅	-	vanadium Pentoxide
Y ₂ O ₃	-	Yttrium oxide
ZnO	-	Zinc oxide
ZrO ₂	-	Zirconium oxide



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